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EVALUATION OF THE FLUSH/FILL AND HIGH-PRESSURE AIR PURGE PROCED--ETC(U)
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EVALUATION OF THE FLUSH/FILL AND HIGH-PRESSURE AIR PURGE PROCEDURES FOR CONVERTING ARMY VEHICLES TO SILICONE BRAKE FLUID

by

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James H. Conley
and
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February 1982

U.S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT COMMAND
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Tests were undertaken to evaluate flush/fill and high-pressure air purging techniques for converting Army vehicles to silicone brake fluids. The flush and fill procedure gave high residual polyglycol levels, particularly in vehicles with calipers. The M-151 series can be effectively converted by this method.

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The high-pressure air purge technique introduces the safety concerns of flammability and toxicity of the mists and vapors. Literature data on the health hazards of glycol materials indicated that personnel exposure should not be allowed, and that atmospheric levels should be monitored to insure compliance with regulations. In addition, the bioassay program at National Cancer Institute (NCI) should be monitored for the possible carcinogenicity of potential breakdown products. The flammability of mists and vapors of polyglycol fluids indicates that these mists and vapors should not be vented in inclosed areas especially in the vicinity of an ignition source.

The air entrainment of a polyglycol and the three silicone brake fluids were measured at various temperatures by the use of a turbidimeter. The air entrainment of the silicones was, in general, lower than that of the polyglycol.

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EVALUATION OF THE FLUSH/FILL AND HIGH-PRESSURE AIR PURGE PROCEDURES FOR CONVERTING ARMY VEHICLES TO SILICONE BRAKE FLUID

I. INTRODUCTION

In 1967, the U.S. Army began developing a multipurpose silicone-based brake fluid which, because of its properties, would replace all three of the conventional brake fluids currently in use as well as eliminate the problems associated with the use of these fluids.

Brake Fluid, Silicone (BFS), MIL-B-46176[1] which was developed in conjunction with industry by the U.S. Army Mobility Equipment Research and Development Command (MERADCOM) was approved for use in 1980. The MERADCOM-proposed conversion method, wipe and clean, which involves system disassembly and which was successfully tested in comprehensive field tests was found to be impractical due to its labor requirements and cost.[2]

Because of the configuration of hydraulic braking systems and the chemical properties of the two fluids, contamination of the old fluid results in those systems which are not disassembled. MERADCOM began investigating alternate procedures for conversion which could be used to alleviate the residual contamination problem inherent in procedures which do not involve disassembly.

The flush/fill method, which involves flushing the system with silicone brake fluid, was investigated and found to be ineffective especially in disc brake calipers. An air-purging technique used by the Navy and investigated by the U.S. Army Tank-Automotive Command (TACOM) involves blowing the old polyglycol fluid out of the system by compressed air.[3] This approach raises certain concerns about the safety of such a procedure which includes the flammability and toxicity of these fluids under these conditions. In addition, the use of pressurized air (as well as general conversion procedures) led to the study of the air entrainment properties of these fluids since air is significantly detrimental to brake operation.

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[1] Military Specification MIL-B-46176, *Brake Fluid, Silicone, Automotive, All Weather, Operational and Preservative*, 27 Mar 78.

[2] TACOM Report No. 10-80-03, *Economic Analysis of Converting Army Vehicles to Silicone Brake Fluid (Flush Methodology)*, November 1980.

[3] TACOM Letter to DARCOM, *Air Pressure Purging of Hydraulic Brake Systems*, 18 Dec 80.

The flammability of the mists associated with a high-pressure purge technique creates a hazardous situation if these mists and vapors are vented into the work place. The toxicity data available concerning the polyglycol fluids indicate that worker exposure should be minimized, the work place should be monitored for atmospheric contamination, and the results of current test for carcinogenicity of possible breakdown products should be monitored (as the health protection standard is set at zero for all carcinogens).

The air entrainment properties of the three silicone fluids and a polyglycol fluid have been measured at various temperatures, and these tests indicate that the silicones entrain less air and dispel it more quickly than does the polyglycol fluid.

II. DETAILS OF TESTS

1. Evaluation of Flush/Fill Procedure. The objective of this evaluation was to determine the effectiveness of the straight flush/fill procedure in removing used glycol brake fluid.

Three military vehicles were used which had different brake system configurations which are representative of all tactical brake systems and components in terms of fill and bleeder line locations (Figure 1). The three vehicles were an M-151 (¼-ton), an M-880 (1¼-ton), and an M-812 (5-ton).

The data generated in this study were:

a. The amount of residual polyglycol in the wheel cylinders and master cylinders after flush/filling with BFS.

b. The reduction in water content of used glycol brake fluid when preflushed with new polyglycol fluid.

c. The amount of residual glycol in a wheel cylinder after application of an aspiration method.

M-151 (All wheel cylinders identical).

Test 1 — Flush/Fill with BFS.

Test 2 —
- Flush/Fill with BFS.
- Aspirate one wheel cylinder with a 100-ml syringe.
- Add additional BFS.

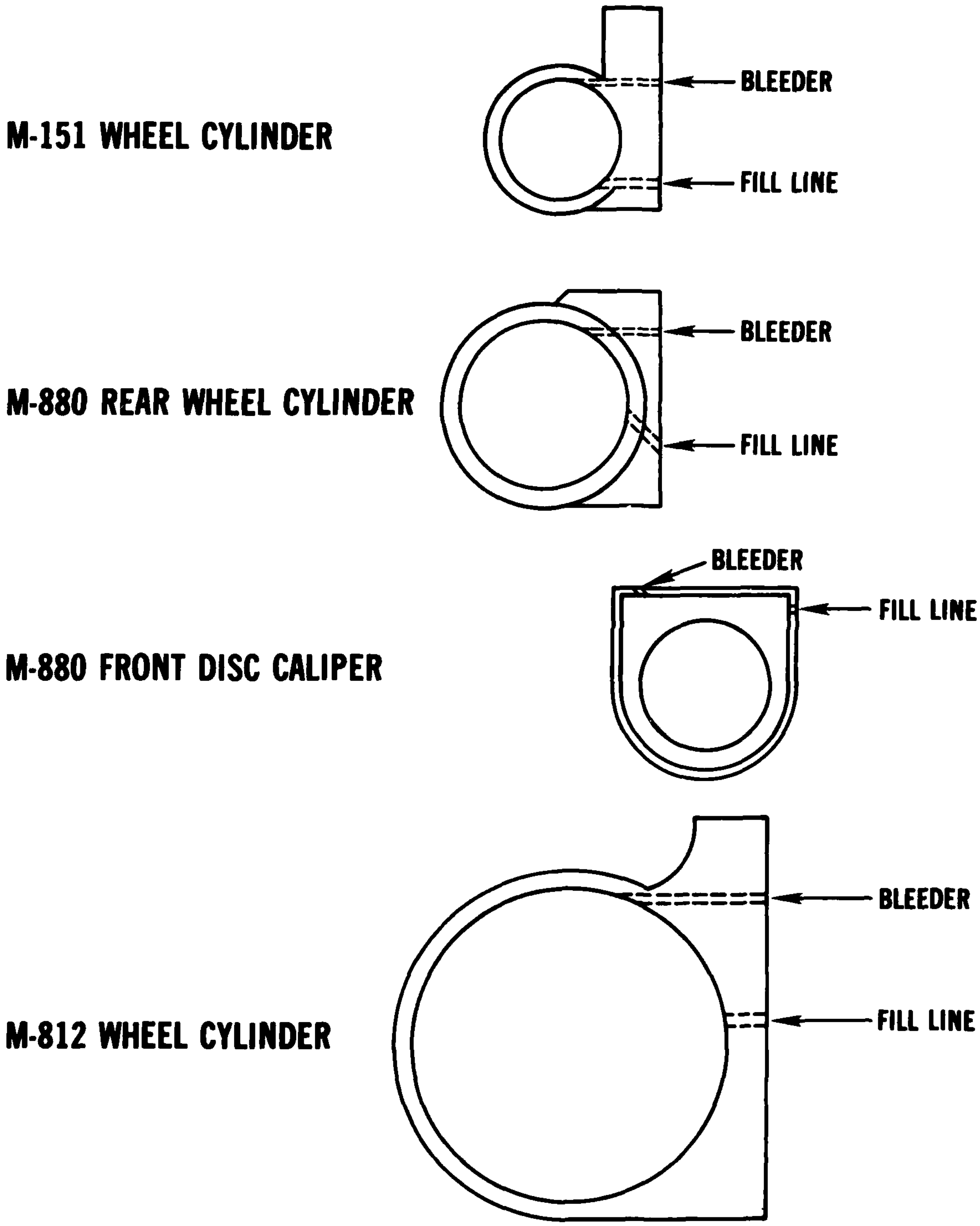

Figure 1. Cross-sectional diagrams of wheel cylinders showing location of line and bleeder holes.

M-880 — Flush/fill with BFS.

M-812.

Test 1 — ● Withdraw a small sample to determine the water content of the brake fluid.

● Flush with a threefold excess of new glycol.

● Flush/fill with BFS.

Test 2 — ● Aspirate a wheel cylinder in the laboratory.

The samples were obtained by removing the sealed cylinders from the vehicles, and carefully draining the contents into a plastic bottle. Water contents were determined using the Karl Fischer Method (ASTM D-1744). The residual glycol/BFS levels were measured by volumetric methods. A wheel cylinder from the right center wheel of the M-812 was mounted in its normal position, filled with glycol fluid, and aspirated by using a syringe and a 6-in., 14-gauge hypodermic needle which was bent to a 60-degree angle.

2. Flammability of Glycol Fluids. The objective of this study was to evaluate the proposed air purge procedure for polyglycol brake fluid in regard to the potential of mist and vapor formation and the associated hazards of flammability or explosion in closed areas such as automotive maintenance shops.

The U.S. Army Fuels and Lubricants Research Laboratory (AFLRL) has the expertise and equipment necessary for this type of research. This group investigated the flammability of W-B-680 brake fluid under high-pressure purging conditions.

For these tests, a used wheel cylinder from a 5-ton truck complete with spring, cups, and pistons was mounted in a position similar to in-service use. A fluid reservoir was connected to the inlet which could be pressurized by nitrogen. These tests were recorded on film.

Initially tests at 50,100, and 150 lb/in.^{2} were conducted without an ignition source to visually document the mist cloud formed in this procedure. In the flammability tests and acetylene torch, a hot manifold and an electric spark were used as the ignition source.

3. Toxicity and Health Hazards of Polyglycol Brake Fluid Components. The objectives of this study were:

● To identify the toxicological and health hazard characteristics of the common polyglycol brake fluid components.

- To provide a preliminary assessment of the potential health hazards associated with worker exposure occupationally to these compounds, in particular, with respect to the vapors and mists associated with air purging of hydraulic brake systems.

The six most widely used polyglycol brake fluid components were targeted, and a preliminary literature search was conducted by personnel of the U.S. Army Medical Bioengineering Research and Development Laboratory (USAMBRDL) to determine the known scientific information on the toxicological properties, adverse health effects, and current health protection standards of these fluids (Appendix A). In addition to these fluids, it is recognized that usage of these fluids may result in the presence of some breakdown products and some of the possible breakdown products are, also, suggested.

The toxicological and health hazard data for the six most commonly used brake fluid components was extracted from the literature. The sources of information consulted are listed in the REFERENCES. These compounds and their Chemical Abstracts registry numbers are:

- Ethylene glycol, CAS 107-21-1.
- Ethylene glycol monomethylether, CAS 109-86-4 (or 2-Methoxyethanol, Methylcellosolve).
- Ethylene glycol monoethyl ether, CAS 110-80-5 (or z-Ethoxyethanol, cellosolve).
- Ethylene glycol monobutyl ether, CAS 111-76-2 (or 2-Butoxy ethanol, butyl cellosolve).
- Diethylene glycol, CAS 111-46-6.
- Diethylene glycol monobutyl ether, CAS 112-34-5 (or 2-(2-Butoxyethoxy) ethanol).

The possible existence of breakdown products in used fluids led to the suggestion of the possible materials in Appendix B. The materials have not been shown to be present but would be candidates for a preliminary screening for degradation products.

4. Air Entrainment of Brake Fluids. The objective of this study was to determine the air entrainment properties of the BFS compared to the polyglycol at various temperatures. The air entrainment of the three silicone fluids and a VV-B-680 glycol fluid was measured at six temperatures using a turbidimeter. The air entrainment resulting from pouring the fluids into a container was also investigated. A turbidimeter measures the concentration of particles in fluids by analysis of light scattered at a 90-degree angle from the incident beam. The higher the intensity of scattered light, the higher the turbidity (the higher the amount of entrained air).

Each fluid was stabilized at 108°F, 77°F, 65°F, 40°F, 25°F, and 0°F and then shaken vigorously for 15 s. After shaking, the samples were returned to the oven or cold box at the specified temperatures and allowed to stand for 15 min. The turbidity measurements were then taken (Appendix C). The process was repeated at the different temperatures after 20 and 30 min. The 30-min readings were checked only at 108°F and 77°F, since they showed only a very slight change after the 20-min reading.

A second procedure was performed at 77°F which involved pouring the test fluids from one container into the measuring tube. This procedure did not introduce any appreciable amount of air into the samples and was abandoned.

III. RESULTS OF TESTS

This evaluation of the flush/fill procedure for conversion to BFS indicated that, although the M-151 (Table 1) vehicles could be effectively converted, the majority of vehicles could not be (Tables 2 and 3). The systems which had disc brakes were, particularly, bad. Flushing with fresh glycol fluid removed about 70 to 75 percent of the old (wet) fluid and none of the procedures removed the sludge from the inside of the wheel cylinders. Aspiration (Table 1) was effective at removing about 95 percent of the used glycol fluid (but not sludge). However, this technique is sensitive to the sludge particles which would clog the needle of the syringe used in the procedure.

These tests indicated the heavy mist formation associated with a high-pressure purge and the associated flammability hazard. The mist became finer as the pressure increased, and the higher vapor pressure of fine droplets contributes to the hazard. The volume of fluid remaining after the high-pressure purge for 5 min was 20 percent.

This testing clearly showed that a hazardous condition is created if the high-pressure air purge were to be used in the presence of a source of ignition (Table 4). Furthermore, literature data show that some of the commonly used brake fluid solvents produce an explosion hazard with air in the range of 1.1 to 19.8 percent. Because of this, the hazard of a major explosion is much more severe than the potential of localized flashing and burning, which also exists under such working conditions.

Based on available toxicity data and health protection standards, any method for removing polyglycol brake fluid from in-use vehicles should minimize personnel exposure, particularly by inhalation. The atmospheric levels of these compounds should be regularly monitored to insure compliance with TLV-TWAs and proposed TLV-STELs (Appendix A) for the glycol constituents. In addition, the progress and results of the NCI carcinogenicity bioassay testing program should be monitored to insure that the compounds and breakdown products are not carcinogenic (Appendix B). If any of these compounds are proven carcinogens, then immediate action is required to insure compliance with the current U.S. regulatory policy prohibiting exposure to known carcinogens.

Table 1. Results of Flush/Fill Procedure with BFS in M-151[1]

	Percentage after BFS Flush/Fill	
Cylinder	Vol BFS (%)	Vol Glycol (%)
Left Rear	100	0
Right Rear	100	0
Left Front	100	0
Right Front	100	0

Test 1 Results

All glycol removed by flush/fill.

There was a small amount (½ mm) of sludge[2] remaining on the entire surface of the wheel cylinder.

Time for all wheels = 30 min.

Test 2 Results

All glycol removed.

None of the sludge found in test 1 was removed.

Time for all wheels = 1½ h.

1 Examined two wheel cylinders (1 front and 1 back). One of the pistons in each cylinder was non-functional

2 The sludge is a mixture of solid and semi-solid polyglycol degradation products, water, oxidation products of the fluid with aluminum and cast iron cylinder materials. and rubber particulates.

Table 2. Results of Wheel and Master Cylinder Contents After BFS Flush/Fill in M-880 (Bumper #WE2)*

Cylinder	Vol Silicone Brake Fluid (%)	Vol Glycol (%)
Left front caliper	12	88
Right front caliper	13	87
Right rear	32	68
Left rear	37	63
Master cylinder	100	0

*Vehicle mileage was 18,766 mi.
All cylinders were in good condition.

Volume of front calipers = 82 ml
Volume of wheel cylinders = 15 ml.

Time to flush/fill = 45 min.

Table 3. Results of Wheel and Master Cylinder Contents After Fresh Glycol Pre-flush and Silicone Brake Fluid Flush/Fill in M-812 (Bumper #MB 203)*

Test 1

Wheel Cylinder	Water Content in Brake System (before fresh glycol pre-flush) Wt Water (%)	Water Content in Brake System** (after fresh glycol pre-flush) Wt Water (%)
Left Rear	0.48	0.18
Right Rear	0.76	0.34
Left Center	0.42	0.15
Left Front	0.87	0.29
Right Front	0.16	0.23
Average	0.54	0.24

Percentages after BFS Flush/Fill

Cylinder	Vol Silicone Brake Fluid (%)	Vol Sludge (%)	Vol Glycol (%)
Left Rear	15	5	80
Right Rear	10	5	85
Left Center	14	1	85
Left Front	15	8	77
Right Front	10	8	82
Master Cylinder	91	9	

Total volume of wheel cylinder = 105 ml
Time for all wheels = 45 min

Test 2

Percentages after BFS Flush/Fill and Aspirator

Cylinder	Vol BFS (%)	Vol Sludge (%)	Vol Glycol (%)
Right Center	95	No sludge removed	5

Estimated time for all wheels = 2¼ h

*The left center wheel cylinder was in excellent condition. Both the left front and right front wheel cylinders were leaking and badly corroded. The right center wheel cylinder had already been replaced before the test. All wheel cylinders were in very bad condition, but all were reinstalled on the vehicle because it had to be back in service. The mechanics said that no replacements were available, and it would take about three weeks to obtain new ones. Vehicle mileage was 3,783 mi.
**Water content of new fluid = 0.13%.

Table 4. Hazards Using Ignition Sources

Sample No.	Pressure ($lb/in.^2$)	Ignition Source	Fluid Vol Remaining (ml)	Test Results
1	50	None	60	Initially a spray of large droplets followed by a very fine mist/fog.
2	50	Acetylene Torch	60	The initial mist was ignited by the torch and burned until the fluid/air ratio became too low to support burning.
3	100	None	50	A spray of large droplets followed by a very finely dispersed spray/fog.
4	100	Acetylene Torch	50	The initial spray was ignited by the torch and burned until the fluid/air ratio became too low to support burning.
5	150	None	40	A spray of large droplets followed by a very finely dispersed spray/fog.
6	150	Acetylene Torch	40	The initial spray was ignited by the torch and burned until the fluid/air ratio became too low to support burning.
7	150	None	20	1 min – steady mist 2 min – steady mist 3 min – steady mist 4 min – intermittent mist 5 min – intermittent mist

Air entrainment properties of the silicone fluids as compared to a glycol fluid were found to be lower than those of the polyglycol (except after 5 min at 77°F) and that the Union Carbide BFS was the least likely to entrain air (Table 5 and Appendix C). Even though air entrainment is to some extent a function of viscosity, the surface tension of silicones appears to take precedence (Figure 2), thereby giving a lower air entrainment for the silicone fluids. Pouring the silicones did not introduce any appreciable amount of air after 1 min and so no further testing was done (Table 6).

IV. CONCLUSIONS

The straight flush/fill procedure is not completely effective at used polyglycol removal (except in the M-151 vehicles) and is worst for calipers.

The air purge technique, while more efficient than flush/fill, leaves polyglycol in the system and generates heavy mists and vapors. The flammability and toxicity of these mists and vapors indicate that hazards exist, that personnel exposure should be minimized, and the atmospheric levels of these materials should be monitored to insure compliance with regulations.

The air entrainment properties of the silicones are less than those of the polyglycols.

Table 5. Turbidity Measurements, NTU – Severe Agitation

Sample	Temp (°F)	NTU Ratings		
		After 5 min	After 20 min	After 30 min
Wagner H-79, HB	108	13	4.2	3.3
	77	20	3.8	3.5
	65	22	3.6	
	40	65	4.5	
	25	95	5.7	
	0	245	110	
Dow 1000, BFS	108	0.8	0.5	0.5
	77	205	0.5	0.4
	65	1.7	1.6	
	40	1.7	1.6	
	25	1.8	1.7	
	0	2.6	1.8	
GE 1001, BFS	108	1.0	0.9	0.9
	77	180	1.2	0.8
	65	1.5	0.9	
	40	2.8	0.7	
	25	0.9	0.9	
	0	8.0	7.5	
UC 1002, BFS	108	0.8	0.7	0.7
	77	125	0.8	0.6
	65	0.9	0.9	
	40	0.9	0.8	
	25	1.0	0.8	
	0	1.2	0.9	

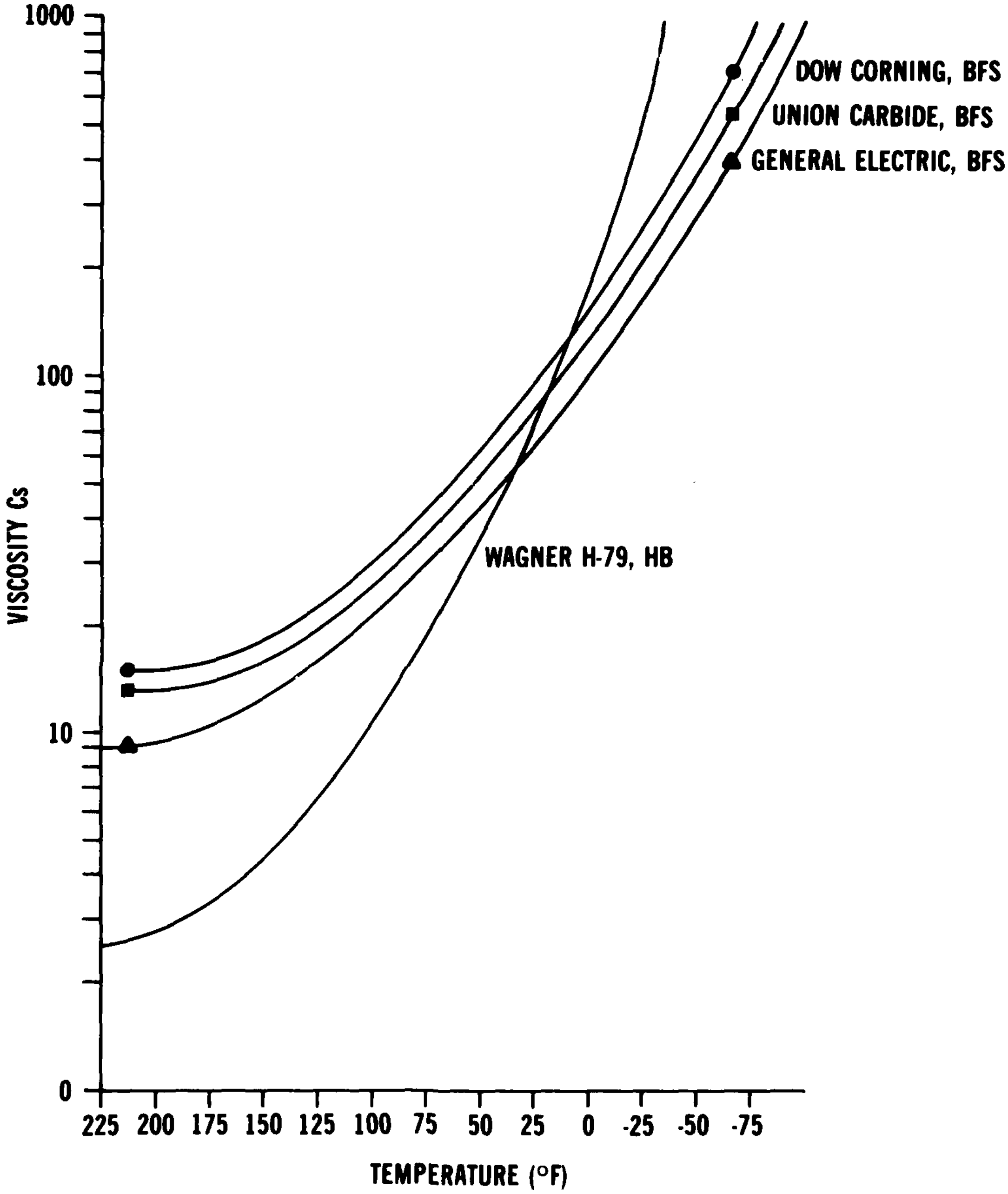

Figure 2. Viscosity as a function of temperature for a polyglycol and three silicone fluids.

Table 6. Turbidity Measurements, NTU – Mild Agitation

Fluid Sample	Temp (°F)	NTU Ratings
		After 1 min
Wagner H-79, HB	77	2.5
Dow 1000, BFS	77	0.4
GE 1001, BFS	77	0.9
U.C. 1002, BFS	77	0.7

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APPENDIX A

TOXICOLOGIC PROPERTIES AND POTENTIAL HEALTH EFFECTS OF SELECTED POLYGLYCOL BRAKE FLUID COMPONENTS: A PRELIMINARY LITERATURE SURVEY

A. Toxicologic Properties and Potential Health Effects.

1. Diethylene glycol

a. Toxicologic Properties:

(1) Irritation Dose:

Skin-humans 112 mg/3D-IMLD
Eye-rabbit 50 mg MLD

(2) Toxic Dose:

Oral-humans LD50: 1000 mg/kg
Oral-rabbit LD50: 14800 mg/kg
Oral-mouse LD50: 23700 mg/kg
Inhalation-mouse LCLo: 130 mg/m^3/24
Subcutaneous-mouse LDLo: 5 gm/kg
Oral-dog — LD50: 9000 mg/kg
Oral-cat — LD50: 3300 mg/kg
Oral-guinea pig LD50: 7800 mg/kg
Intravenous-rabbit LD50: 2000 mg/kg

(3) Aquatic Toxicity Rating:

TLm 96: over 1000 ppm

b. Human Health Effects — Symptoms:

Nausea, vomiting, epigastric, diarrhea, cyanosis, drowsiness, fatigue, coma, pulmonary edema, albuminuria, oliguria, uremia.

2. Diethylene glycol monobutyl ether or Ethanol, 2(2-Butoxyethoxy)

a. Toxicologic Properties:

(1) Irritation Dose:

Eye-rabbit 5 mg SEV

(2) Toxic Dose:

Oral-rat LD50: 6500 mg/kg
Intraperitoneal-mouse LD50: 850 mg/kg
Skin-rabbit LD50: 4120 mg/kg
Oral-guinea pig LD50: 2000 mg/kg

(3) Aquatic Toxicity Rating:

TLm 96: 100 — 10 ppm

b. Human Health Effects — Symptoms:

Weakly toxic with symptoms similar to ethylene glycol

3. Ethylene glycol

a. Toxicologic Properties:

(1) Irritation Dose:

Eye-rat 12 mg/m^3/3D
Skin-rabbit 555 mg open MLD
Eye-rabbit 111 mg
Eye-rabbit 12 mg/m^3/3D
Eye-rabbit 1440 mg/6H/MOD

(2) Toxic Dose:

Oral-child TDLo: 7400 mg/kg TFX:SYS
Oral-human LDLo: 710 mg/kg
Inhalation-human TCLo: 10000 mg/m^3 TFX:SYS
Oral-rat-LD50: 5840 mg/kg

Intraperitoneal-rat-LD50: 5300 mg/kg
Subcutaneous-rat-LD50: 5300 mg/kg
Intraveneous-rat-LDL0: 2800 mg/kg
Intramuscular-rat-LDLo: 3300 mg/kg
Oral-mouse-LD50: 7500 mg/kg
Intraperitoneal-mouse: LDLo: 1700 mg/kg
Subcutaneous-mouse: LDLo: 2700 mg/kg
Intravenous-mouse: LD50: 3300 mg/kg
Oral-cat-LD50: 2000 mg/kg
Subcutaneous-cat-LDLo: 1000 mg/kg
Intraperitoneal-rabbit-LDLo: 1000 mg/kg
Intravenous-rabbit-LDLo: 5 gm/kg
Intramuscular-rabbit-LDLo: 5500 mg/kg
Oral-guniea pig-LD50: 6610 mg/kg
Subcutaneous-guinea pig-LDLo: 5000 mg/kg

(3) Aquatic Toxicity Rating:

TLm 96: 1000 — 10 ppm

b. Human Health Effects — Sympιoms:

Conjunctivitis, nausea and vomiting, abdominal pain, weakness, naydriasis, cyanosis, tremor and convulsions (fits), areflexia, narcosis (paralysis) and coma, albuminuria, humaturia, anuria, and lymphocytosis.

4. Ethylene glycol monobutyl ether; or Ethanol, 2-butoxy

a. Toxicologic Properties:

(1) Irritation Dose:

Skin-rabbit-500 mg open MLD
Eye-rabbit — 18 mg

(2) Toxic Dose:

Inhalation-human-TCLo: 195 ppm/8H TFX:IRR
Oral-rat-LD50: 1480 mg/kg
Inhalation-rat-LCLo: 500 ppm/4H
Intraperitoneal-rat-LD50: 550 mg/kg
Intravenous-rat-LD50: 340 mg/kg

Oral-mouse-LD50: 1230 mg/kg
Inhalation-mouse-LC50: 700 ppm
Intraperitoneal-mouse-LD50: 536 mg/kg
Subcutaneous-mouse-LDLo: 500 mg/kg
Intravenous-mouse-LD50: 1130 mg/kg
Oral-rabbit-LD50: 320 mg/kg
Intravenous-rabbit-LD50: 280 mg/kg
Oral-guinea pig-LD50: 1200 mg/kg
Skin-guinea pig-LD50: 230 mg/kg

(3) Aquatic Toxicity Rating:

TLm 96: 1000 — 100 ppm

b. Human Health Effects — Symptoms:

Irritation of eyes and respiratory tract; headache toxic to liver and kidney by long-term exposure at high vapor concentration in air, resulting in hepatic hemoglobinemia and albuminuria; also toxic by skin absorption.

5. Ethylene glyc l monomethyl ether; or Ethanol, 2-methoxy

a. Toxicologic Properties:

(1) Irritation Dose:

Skin-rabbit: 483 mg/24H MLD
Eye-rabbit: 97 mg
Eye-guinea pig: 10 mg/MLD

(2) Toxic Dose:

Oral-human-LDlo: 3380 mg/kg
Inhalation human-TCLo: 25 ppm TFX:CNS
Oral-rat-LD50: 2460 mg/kg
Inhalation-rat-LCLo: 2000 ppm/4H
Intraperitoneal-rat-LDLo: 1200 mg/kg
Intravenous-rat-LD50: 2140 mg/kg
Inhalation-mouse-LC50: 1480 ppm
Oral-rabbit-LD50: 890 mg/kg
Inhalation-rabbit-LD50: 1340 mg/kg
Oral-guinea pig-LD50: 950 mg/kg

(3) **Aquatic Toxicity Rating:**

TLm 96: 1000 — 10 ppm

b. **Human Health Effects — Symptoms:**

Irritation of eyes and respiratory tract; hematriria; albuminuria.

6. **Ethylene glycol monoethyl ether; or Ethanol 2-ethoxy**

a. **Toxicologic Properties:**

(1) **Irritation Dose:**

Eye-human: 6000 ppm
Skin-rabbit: 500 mg open MILD
Eye-rabbit: 50 mg MOD
Eye-guinea pig: 10 mg MLD

(2) **Toxic Dose:**

Oral-rat — LD50: 3000 mg/kg
Inhalation-rat-LCLo: 4000 ppm/4H
Oral-mouse-LD50: 4300 mg/kg
Intraperitoneal-rat-LDLo: 1200 mg/kg
Inhalation-mouse-LC50: 1820 ppm
Intraperitoneal-mouse-LD50: 1710 mg/kg
Subcutaneous-mouse-LDLo: 5 gm/kg
Intravenous-mouse-LD50: 3900 mg/kg
Oral-rabbit-LD50: 3100 mg/kg
Skin-rabbit-LD50: 3500 mg/kg
Oral-guinea pig-LD50: 1400 mg/kg
Inhalation-guinea pig-LCLo: 3000 ppm/24H

(3) **Aquatic Toxicity Rating:**

TLm 96: 1000 — 100 ppm

b. **Human Health Effects — Symptoms:**

Headache; dizziness; drowziness; irritation of eyes, tremor; ataxia (defective control of muscles); Romberg's sign; gastro intestinal disturbance; and weight loss.

B. Glossary and Key to Abbreviations

1. Units of Exposure and Units of Dose

mg/kg = milligrams per kilogram
μg = micrograms
p/m = parts per million as a unit of air volume
mg/m^3 = milligrams per cubic meter
gm/kg = gram per kilogram

2. Duration of Exposure

min = minutes
h = hours
d = days
wk = weeks
yr = years

3. Description of Exposure

In order to better describe the administered dose reported in the literature, six abbreviations are used. These terms indicate whether the dose caused death (LD) or other toxic effects (TD) and whether it was administered as a lethal concentration (LC) or toxic concentration (TC) in the inhaled air. In general, the term "Lo" is used where the number of subjects studied was not a significant number from the population or the calculated percentage of subjects showing an effect was listed as 100. The definition of terms is as follows:

TDLo—Toxic Dose Low—the lowest dose of a substance introduced by any route, other than inhalation, over any given period of time and reported to produce any toxic effect in humans or to produce carcinogenic, neoplastigenic, or teratogenic effects in animals or humans.

TCLo—Toxic Concentration Low—the lowest concentration of a substance in air to which humans or animals have been exposed for any given period of time that has produced any toxic effect in humans or produced a carcinogenic, neoplastigenic, or teratogenic effect in animals or humans.

LDLo—Lethal Dose Low—the lowest dose (other than LD50) of a substance introduced by any route, other than inhalation, over any given period of time in one or more divided portions and reported to have caused death in humans or animals.

LD50—Lethal Dose Fifty—a calculated dose of a substance which is expected to cause the death of 50 percent of an entire defined experimental animal population. It is determined from the exposure to the substance by any route other than inhalation of a significant number from that population. Other lethal dose percentages, such as LD1, LD10, LD30, and LD99, may be published in the scientific literature for the specific purposes of the author. Such data would be published in the Registry if these figures, in the absence of a calculated lethal dose (LD50), were the lowest found in the literature.

LDLo—Lethal Concentration Low—the lowest concentration of a substance in air, other than LC50, which has been reported to have caused death in humans or animals. The reported concentrations may be entered for periods of exposure which are less than 24 h (acute) or greater than 24 h (subacute and chronic).

LC50—Lethal Concentration Fifty—a calculated concentration of a substance in air, exposure to which for a specified length of time is expected to cause the death of 50 percent of an entire defined experimental animal population. It is determined from the exposure to the substance of a significant number from that population.

The following table summarizes the above information:

Category	Exposure Time	Route of Exposure	Toxic Effects: Human	Toxic Effects: Animal
TDLo	Acute or chronic	All except inhalation	Any non-lethal	CAR, NEO ETA, TER
TCLo	Acute or chronic	Inhalation	Any non-lethal	CAR, NEO ETA, TER
LDLo	Acute or chronic	All except inhalation	Death	Death
LD50	Acute	All except inhalation	Not applicable	Death (Statistically determined)
LCLo	Acute or chronic	Inhalation	Death	Death
LC50	Acute	Inhalation	Not applicable	Death (Statistically determined)

4. Skin and Eye Irritation Toxicology Data

The method of testing substances for primary skin irritation given in the Code of Federal Regulations does not include an interpretation of the response. However, some authors do include a subjective rating of the irritation observed. If such a severity rating is given, it is included in the data line as mild ("MLD"), moderate ("MOD"), or severe ("SEV"). The Draize procedure employs a rating scheme which is included here for informational purposes only, since other researchers may not categorize irritation response in this manner.

Category	Code	Skin Reaction
Mild	MLD	Well defined erythema and slight edema (edges of area well defined by definite raising)
Moderate	MOD	Moderate to severe erythema and moderate edema (area raised approximately 1 mm)
Severe	SEV	Severe erythema (beet redness) to slight eschar formation (injuries in depth) and severe edema (raised more than 1 mm and extending beyond area of exposure)

5. Exposure Standards and Guidelines

a. TLV = Threshold Limit Values

b. TWA = Time Weighted Averages

c. STEL = Short Term Exposure Limits

Threshold Limit Value (TLV). The TLV is an ACGIH-recommended upper limit (ceiling) or time-weighted average concentration of a substance to which most workers can be exposed without adverse effect. This concentration may be designated as a ceiling ("CL") or time-weighted average concentration ("TWA"), or as a notation ("SKN"), indicating that even though the air concentration may be below the limit value, significant additional exposure to the skin may be dangerous. The TLVs are taken from *Documentation of the Threshold Limit Values for Substances in Workroom Air* (third edition), Cincinnati: ACGIH, 1976, or its supplement, or from documentation appearing in ACGIH annual reports.

APPENDIX B

POTENTIAL POLYGLYCOL BRAKE FLUID

CONSTITUENT BREAKDOWN PRODUCTS

The following is a partial listing of the compounds that might occur as the result of breakdown of polyglycol brake fluid components, and which may result under conditions of use in Army vehicles.

Potential Breakdown Products

1. Glycolaldehyde
2. Glyoxal
3. Glycolic acid
4. Glyoxylic acid
5. Glycolide
6. Acetaldehyde
7. Acetic acid
8. Acethoxyl acetaldehyde
9. Methoxyacetic acid
10. Ethoxy acetaldehyde
11. Ethoxyacetic acid
12. n-Butoxy acetaldehyde
13. n-Butoxy acetic acid
14. Hydroxyethoxy acetaldehyde

15. Hydroxyethoxy acetic acid (ethylene glycol monoacetic acid)

16. Diglycolic acid

17. Oxalic acid

18. Formaldehyde

DISCUSSION

1. Chemistry

This list of properties is not exhausted. In particular, there are many potential hydroperoxy compounds (i.e., those with -OOH), especially where the hydroperoxy is on a carbon linked to another oxygen. These compounds are not extremely stable, and their isolation and identification would be difficult.

2. Toxicology and Health Effects

A very preliminary screen of the scientific data base on known toxicology and health effects data base has been conducted on these potential breakdown products. Of most significance for evaluation of potential health hazards, two of the compounds listed above, oxalic acid and formaldehyde, were found to be included in the National Cancer Institute (NCI) Bioassay Testing Program of the National Toxicology Program (NTP). The intent of this evaluation program is to conduct carcinogenicity evaluation of compounds suspected to be potential carcinogens. Oxalic acid has been selected for testing through standard NCI oral testing protocols using the mouse and rat. Formaldehyde has been selected for testing through a bioassay program consisting of inhalation exposure to mice.

If proven carcinogens, this implies under current U.S. occupational health protection regulatory policies that exposure in any form is prohibited, as the health protection standard is set at zero for all carcinogens. Given a positive carcinogen testing finding for either of these compounds under the NCI bioassay would, therefore, support the requirement to more thoroughly characterize the chemical composition of polyglycol brake fluids contained in existing Army fleet vehicles to validate the absence of these compounds, or to insure compliance with regulatory policies if these compounds are found to be present.

APPENDIX C

INTERPRETATION OF NEPHELOMETRIC TURBIDITY UNITS (NTU)

Turbidity Range (NTU)	Appearance of Fluid
0-1.0	Clear (No Visible Entrained Air)
1-10	Very Slight Haze (Minute Amount of Entrained Air)
10-40	Visably Hazy (Small Amount of Entrained Air)
40-100	Cloudy (Moderate Amount of Entrained Air)
100-400	Very Cloudy (Large Amount of Entrained Air)

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